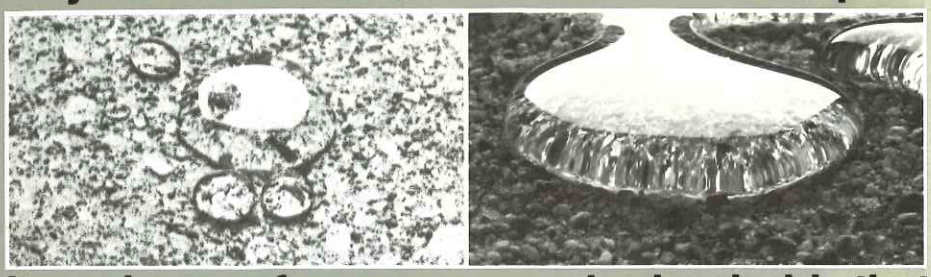
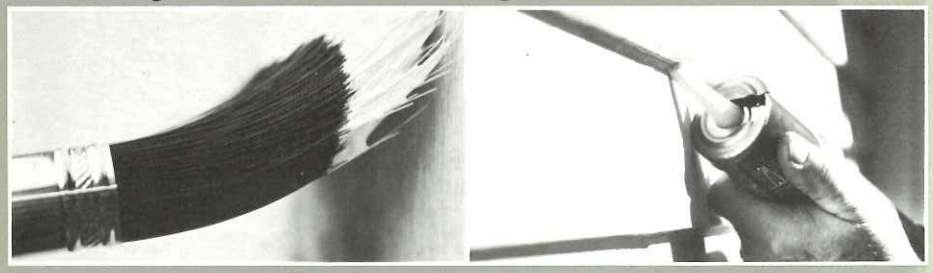
Tullanox™ 500 is a super-hydrophobic fumed silica finding uses in a widely expanding number of industries. Because of its versatility in modifying the properties of other materials when added to them in very small amounts, it is utilized in both liquid and dry formulations.



It renders surfaces so super-hydrophobic that water cannot wet them. Sands, soils and other granular materials thus treated remain dry even underwater. Masonry, wood, cloth, paper, plastic and other surfaces treated with coatings containing Tullanox 500 cause water to bead up in the manner associated with mercury.

As a free flow and anti-caking additive, it is used in powder fire extinguishers, powdered polymers, metals, fertilizers, pigments and other systems consisting of discrete solid particles.



It serves as a thickening and anti-settling agent, with waterproofing characteristics, in paints, sealants, adhesives, greases, inks and similar systems.

It provides reinforcement in epoxies, polyurethanes, synthetic elastomers and other polymers.

These are only a few of the many industrial applications already benefiting from the use of Tullanox 500.

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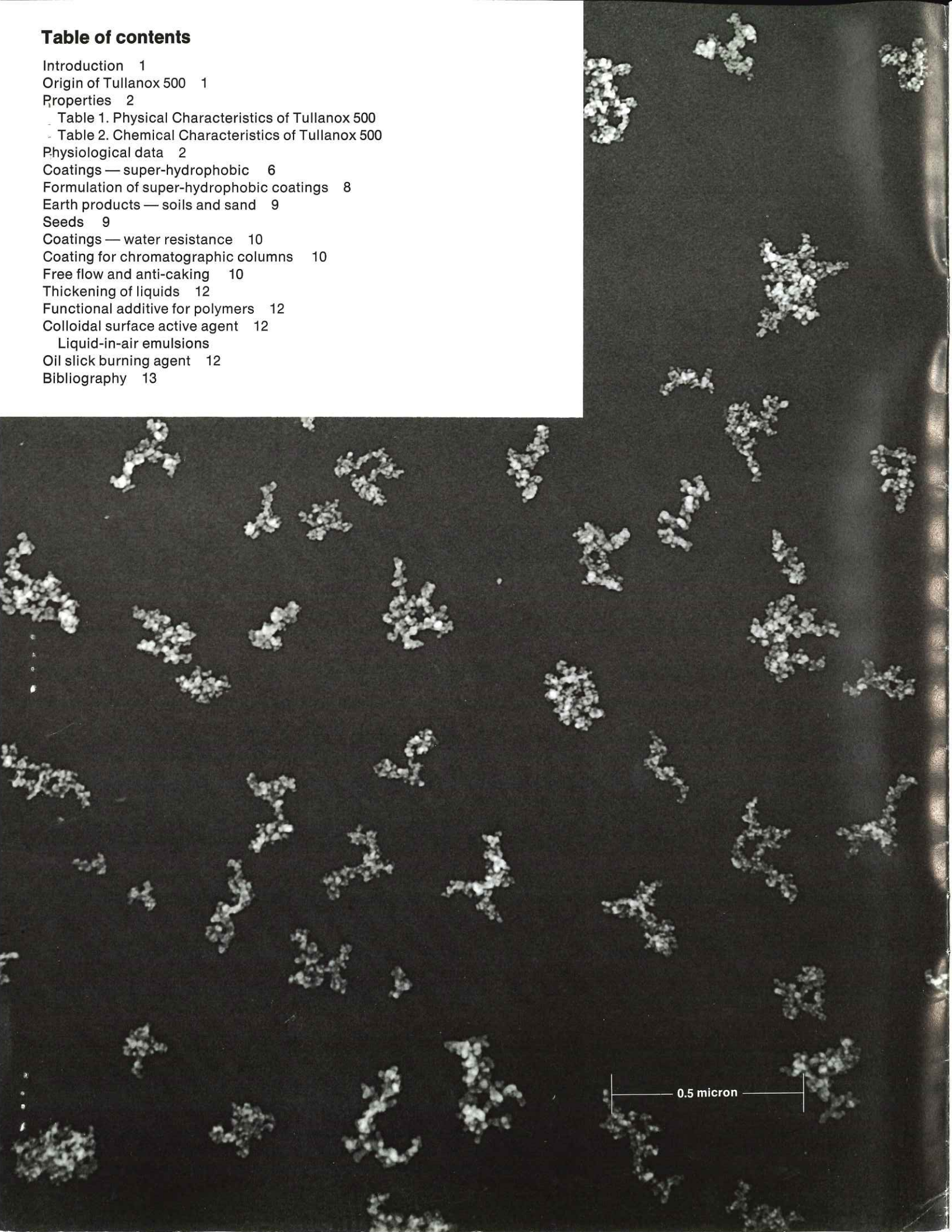


Introduction

Tullanox 500 is an inorganic powdered silica of low bulk density. It has an extremely high surface area which has been modified by reaction with an organic silicone-like compound. This modification imparts a number of unique characteristics to the powder, including dry-lubricant capabilities and a degree of water repellency so extreme that it is termed "super-hydrophobicity".

The submicron particle size and large organic surface area of Tullanox 500 enable it to impart its own properties to those of other systems even when it is present in concentrations as low as 0.1% to 2.0% or less by weight.

Origin of Tullanox 500

Tullanox 500 is derived from a fumed silica base which is over 99.8% pure SiO_2. The hydrophilic hydroxyl groups which normally populate the silica surface are replaced with organic trimethylsiloxyl groups.

The chemical nature of the Tullanox 500 particle surface is depicted in Fig. 1. The hydroxyl groups which are present are so hindered sterically by the surrounding trimethylsiloxyl groups that they are unable to exhibit hydrophilic characteristics. The siloxane groups are intrinsically hydrophobic. The net result is an extremely hydrophobic surface.

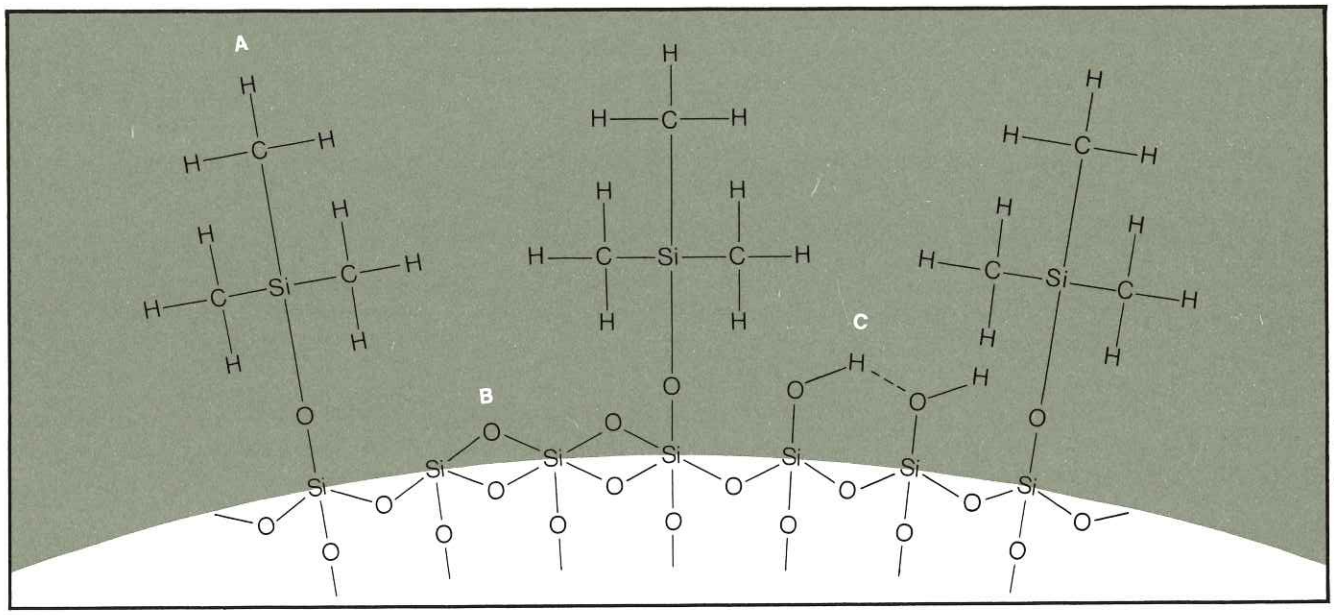


Fig. 1. The structural groups occurring on the surface of Tullanox 500 are (A) trimethylsiloxyl, (B) siloxane and (C) neighboring hydroxyls. The chemically inert Si-C linkages shown are resistant to high temperature oxidation and to solvation by organic solvents.

Left:
Electron micrograph of Tullanox 500. Magnification 90,000X (from a negative print). The randomly-oriented aggregates of fused, solid spheres produce an extremely large surface area. This is one of the factors which make possible the unusual modifications in various properties which can be achieved in many formulations by the addition of small amounts of Tullanox 500.

Properties

The predominant physical attributes of Tullanox 500 are its extremely fine particle size, tremendously large surface area and almost complete lack of cohesive attraction between its own particles.

Chemical properties include a uniquely high degree of water repellency and near absence of surface moisture content, as shown in Fig. 2. Oleophilic behavior is another characteristic of Tullanox 500. If incorporated into an organic liquid which is then allowed to come into contact with water, the particles will not transfer into the water phase as will untreated colloidal silicas.

The physical and chemical properties of Tullanox 500 are summarized in Tables 1 and 2.

Table 1. Physical Characteristics of Tullanox 500

Nominal Particle Size (Diameter in microns)	0.007
Theoretical Surface Area (m^2/gm)	325
Surface Area by N_2-Adsorption Method (m^2/gm)	225
Bulk Density ($lbs./ft.^3$)	3.0
Specific Gravity	2.2
Refractive Index	1.76
Color	White
X-ray Form	Amorphous

Table 2. Chemical Characteristics of Tullanox 500

pH (4% by wt. in 50/50 IPA/H_2O by vol.)	8-10*
Functional Groups	Predominantly surface trimethylsiloxyl groups
Surface ammonia content	Approx. 0.2%*

**Note: Ammonia can be removed by heating the silica at 400°F. for 10-15 minutes or until the pH decreases to approximately 5.5. Approximately 65% of the ammonia can be removed by exposing the silica to ambient air at room temperature for 7 days.*

Physiological data

Dust masks should be used when Tullanox 500 is utilized, since continued inhalation may be harmful. Breathing air containing high concentrations of Tullanox 500 can cause nausea and dizziness. Goggles should be worn, as tests on rabbits have produced slight to moderate eye irritation. Laboratory studies on rats indicate that Tullanox 500 is practically non-toxic by ingestion. The product is not known to be a skin irritant or allergen. Gloves are recommended to avoid the slight skin discomfort caused by adsorption of oils from the skin.

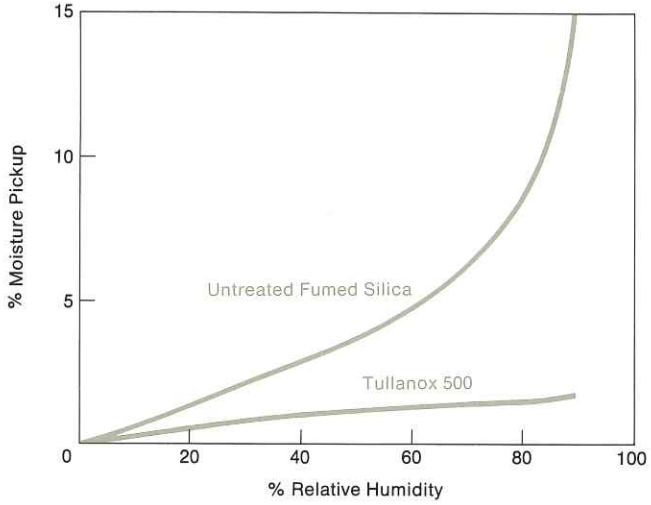


Fig. 2. Typical water vapor adsorption curve of Tullanox 500 at equilibrium conditions, ambient temperature.

Advantages Tulco Tullanox 500 Offers In a Variety of Products

Papers	Provides unique outdoor protection; withstands autoclave temperatures up to 260°F. needed for surgical papers; produces overcoat protection for water sensitive colorants.
Radar antennas and radomes	Eliminates rain water film formation, insures clearer radar signal transmission.
Seeds	Insures germination under adverse wet soil conditions.
Building foundations, walls, tree trunks and plant stems	Modifies vertical surfaces to discourage climbing insects by rendering their adhesion mechanisms inoperable.
Structural concrete forms	Provides easy release and eliminates surface imperfections caused by air voids.
Lawn mowers and snow blowers	Reduces clinging of wet grass and snow.
Textiles	Provides durable protection for awnings, tents, sleeping bags and other fabrics used outdoors.
Sand and other earth products	Produces a completely dry and frost-free sand or soil which can be used for: underground enclosures — as a fill to provide year-round easy access; upgrading secondary roads; insulating oil transmission pipelines; oxygenation of polluted lake bottoms; control of surface rain water run-off; regulating water uptake of potting soils and golf green turfs; and retarding the surface water evaporation of soils.
Building eaves, gutters, transmission wires and insulators, ship's superstructures	Reduces icicle formation with easy ice removal; promotes dropwise condensation of moisture.
Oil absorbents, coated papers, wood products, fibers, straw	Enables efficient selective absorption of oils in the presence of water . . . i.e., industrial wastes and oil slicks.
Automotive	Protects ignition wiring, offers corrosion protection for underbody and exhaust system.
Sporting goods	Produces a shimmering dressing for dry flies, maintains a frictional surface on handles of clubs, bats and rackets by repelling perspiration.
Railway wheels and track	Improves traction by raising the coefficient of friction between wheel surfaces and tracks.

Metal die casting lubricants	Provides lubrication for molten metals, offers easy release, replaces graphite and eliminates discoloration of parts.
Lacquers and varnishes	Provides flatting for polymer systems that are sensitive to moisture, improves wetting of overprint varnishes without high viscosity increase; provides moisture protection in conformal coatings for electronic components.
Masonry treatment	Provides exceptional water shedding capability while maintaining an unpainted appearance.
Wood and metal primers, including zinc rich systems	Provides superior brushability, film toughness and adhesion to substrate with accompanying water repellency; provides higher pigment suspending capability, promotes soft settling.
Metal flaw detection indicators	Small particle size insures ease of detection.
Chromatographic column treatment	Provides a unique hydrocarbon surface for separating mixtures.
Apparel emblem inks and paints	Allows thickening of coatings and provides durability in laundering.
Matches	Retards moisture absorption in match head and striker strips.

Free flow and anti-caking agent

Powdered polymers	Generates high, uniform fluidity of fluidized beds and eliminates electrostatic hang-up on container sidewalls during air conveyance.
Expandable polystyrene	Insures ease of processing without impairing the fusion characteristics of beads.
Dry powder fire extinguishers	Provides free flowing dependability of use even after prolonged periods of storage, increases bulk density of powders by promoting closer loose packing.
Powdered metals	Enables the creation of more uniform mixtures of powdered metals during milling.
Blasting powders	Upgrades the water resistance of compositions used in mining.
Fertilizers	Reduces formation of hard cakes when stored in silos. Provides fluidity for uniform distribution on acreage.
Riot control powders	Provides anti-caking properties and insures dispersibility of the deterrent compositions in any weather.
Resorcinol and oily powders	Reduces tack and produces fluidity.
Paradichlorobenzene cakes	Provides controlled solvation of cakes in sanitary applications.
Powdered insecticides	Facilitates more uniform distribution of dust onto plants and shrubs.
Powdered pigments	Keeps pigments free flowing, improves electrical character of reproductive toners, produces sharper contrast in electrostatic dry printing.
Target aircraft and meteorological rocket vapor trails	Provides increased dispersibility with resulting improvement in visibility.

Thickening agent

Lithographic inks	Improves the hydrophobic character of water sensitive ink systems.
Greases	Allows for the thickening of oils to produce greases of low thixotropy and high resistance to water and elevated temperatures.
Sealants	Produces high viscosity systems manifesting low thixotropic behavior. Adds water resistance.

Functional polymer additive

Epoxies	Provides viscosity, strength and resistance to humidity for automotive body solder and adhesives.
RTV Silicone rubbers	Provides high reinforcement with greatly improved tear resistance without appreciable thickening.
Tooth filling compounds	Provides reinforcement, whiteness and water repellency.
Polyurethanes	Provides flatting and reinforcement without the harmful effects of introducing particle-associated moisture.
Man-made fibers	Provides unique colloidal properties in fibers, can be uniformly dispersed throughout the mass. Provides controlled solvation of water soluble fibers.
Phosphonitrilic fluoroelastomers	Increases modulus, tensile strength and hardness, provides resistance to high temperature.
Specialty rubbers	Provides a carrier base for liquid anti-oxidants, insures uniform distribution, prevents migration and blooming.

Colloidal surface active agent	
Water-in-oil emulsions	Produces high viscosity emulsions having exceptional phase stability for use in insecticides, creams, salves.
Oil-in-water emulsions	Produces unique emulsions without the need for organic surfactants when used in conjunction with untreated fumed silicas or aluminas. For use in oil well drilling muds, industrial compounds and metal working lubricants.
Water-in-air emulsions	Can completely divide water into tiny droplets, encapsulate and convert them to a free flowing powder. Provides a fluffy bed for germination of hard-to-grow seedlings. Enables transplanting without damage to filamentous root structure.
Burning agent	
Oil slicks	Provides an efficient wicking action for removal of floating oil by burning. After burning, hardened mass can be easily collected.

Coatings — super-hydrophobic

By incorporating a high ratio of Tullanox 500 to resin binders, completely waterproof — that is, super-hydrophobic — coatings can be created.

The high performance of Tullanox 500 in these protective coatings is the result of the synergistic effect of combining two separate contributions to water repellency: hydrophobicity and coating surface roughness. Hydrophobicity is supplied by the organic surface groups of the particles. In addition, a super-hydrophobic coating made with Tullanox 500 contains a vast number of tiny particles per unit surface area projecting from the substrate. It is estimated that a monolayer of the coating would consist of 2×10^{12} primary particles per square centimeter. This micro-roughness tends to hold water droplets or films slightly above the coated surface, thus reducing the van der Waals forces of attraction between the two. This results in entrapment of air beneath the liquid layer and the creation of a high water shedding capability. The same effect is seen in nature, in insects and foliage which repel water so efficiently that a sheen or "gaseous plastron"[1] effect is observed when they are submersed in water.

The net effect of these two properties is to produce an extremely high angle of contact between water droplets and coated surfaces, usually on the order of 138°. In effect, water acts toward the surfaces in the manner in which droplets of mercury would be expected to behave. This effect is illustrated in Fig. 3.

Super-hydrophobic coatings[2,3] to eliminate obscuring water films from radar antennas or dome enclosures during rainy weather have been developed utilizing Tullanox 500. Results of extensive tests[4] show that hydrophobic silicon dioxide coatings exhibit a greater degree of water repellency and a lower tilt angle requirement for water run-off than any other coatings, waxes or silicone treatments tested.

Super-hydrophobic coatings optimize the surfaces of wooden, metal or plastic forms used for casting concrete. The layer of air entrapped between the mold and the wet cement by the coating assures easy removal of the forms after hardening. The concrete surface produced is remarkably smooth and free of surface imperfections, because air bubbles which normally gather at the form interface are vented through the air layer.

Release agents for ice are also an important use for these coatings. Applied to surfaces exposed to the elements, they repel water. Icicle formation is retarded. If ice does form under extreme conditions, it is very loosely attached to the substrate and can be easily removed by mechanical means.

Specialty papers, textiles and non-wovens[5] can be made super-hydrophobic by the application of coatings containing Tullanox 500.

Applications include substrates used as building insulations, specialty packaging and filter media used for absorbing oils from streams of oily water. Coated substrates are particularly valuable in cleaning up oil slicks. Formulations can be adapted for aerosol application for waterproofing of tenting, awning and sail materials, apparel — for outdoor work and sports — and sporting items including dry flies. Aerosols can also be used for undercoating automobiles and for maintaining friction on handles of tools and sporting equipment by repelling perspiration.

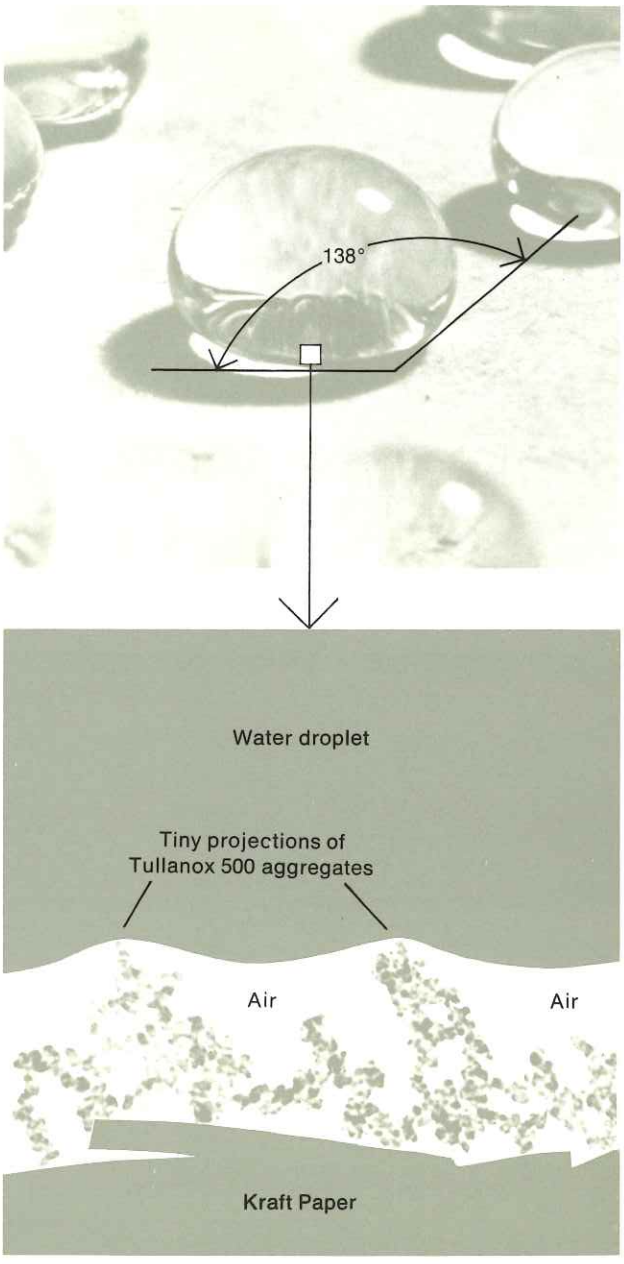


Fig. 3. Where water droplets rest on surfaces coated with Tullanox 500, they are supported on the points of millions of microscopic hydrophobic projections. A layer of air is thus trapped between the water and the surface of the substrate.

[1] *See Bibliography, page 13.*

A super-hydrophobic coating containing Tullanox 500 converts a corrugated paperboard mock-up into a she-worthy craft.

Improvements in the coefficient of friction between moving, contacting metal surfaces[6] can be attained with these coatings. This offers utility for rail and cable transportation systems.

Vertical surfaces can be rendered nearly inaccessible to larger climbing insects by covering with super-hydrophobic coatings. The adhesion mechanisms on the insects' feet require surface wetting for efficient operation. Tullanox 500 minimizes this attraction through a combination of hydrophobicity and the irregularity of of its surface.

Super-hydrophobic coatings on various substrates are being studied as an artificial gill for underwater divers.

Formulation of super-hydrophobic coatings

Super-hydrophobic coatings can be produced in various ways: 1) As a liquid formulation containing polymeric binders; 2) As a dry formulated powder coating applied by fluidized bed or electrostatic coating techniques; and 3) As a dry powder dusted onto tacky surfaces. (This third technique is discussed in the section titled EARTH PRODUCTS, page 9.)

In preparing liquid coatings, Tullanox 500 is usually present in concentrations of 1% to 5% by weight. The higher the concentration, the whiter or hazier the final coating appears.

Examples of binders for liquid coatings include commercially available acrylic, alkyd and silicone resins. Vehicles may be alcohols, ketones or hydrocarbons.

A typical formula is given below. The normal range for the ratio of Tullanox 500 to resin binder is from 1:0.75 to 1:1.6 by weight. If the ratio of Tullanox 500 to binder is decreased, the hydrophobic effect will be decreased accordingly, but the adhesion of the coating and its abrasion resistance will be improved.

Ingredients	% by weight
Tullanox 500	5.0
SR-516 Silicone Resin Adhesive* (50% solids in toluene)	11.8
Toluene	51.4
Isopropyl Alcohol	31.8
	100.0%

This formulation produces good super-hydrophobicity. The concentration of Tullanox 500 relative to resin binder concentration can be increased to give greater hydrophobicity, with a sacrifice in durability of the coating.

Effective liquid based coatings are also attained by use of powdered polymer binders which are not soluble in the organic liquid medium used to disperse Tullanox 500. The powders may be either thermoplastic or thermosetting in nature. After application of the dispersion, heat is used to evaporate the medium and to set and bind the Tullanox 500 particles to the substrate. Coatings deposited using a concentration of Tullanox 500 equal to 5% to 10% of the weight of the resin binder produce super-hydrophobic coatings. The heat-resistant character of Tullanox 500 allows these dispersion coatings to be activated using temperatures as high as 400°F.

Tullanox 500 itself cannot be dispersed in water. Aqueous coating systems, however, can be prepared by using a suspending agent and high shear dispersion equipment. A typical concentration is 1% Tullanox 500 by weight, with the addition of 0.5% of suspending aid — for example, Carbopol 941**— which also acts to bind the hydrophobic silica to the coated substrate. When these ingredients have been thoroughly blended in water, the pH is brought to 7.0 by the addition of a very small amount of ammonia or other base to activate the thickening of the mixture by the Carbopol 941. Small amounts of acrylic latexes can also be added to improve binding. These preparations display limited shelf life and therefore should be used soon after preparation.

Dry coatings applied by using conventional powder coating methods are capable of high degrees of abrasion resistance and adhesion. Using electrostatic spray or fluidized bed techniques, dry powder blends of Tullanox 500 and fine resinous powders are deposited simultaneously on substrates. Heat is then used to activate the powder resin to allow wetting of the Tullanox 500 particles and subsequent bonding to the substrate. Excellent results have been achieved with

Inspection of an underground enclosure utilizing frost-free hydrophobic sand as a fill which provides year-round easy access.

** General Electric Co., Silicone Products Dept., Waterford, N.Y. 12188*

*** B.F. Goodrich Chemical Company, 3135 Euclid Ave., Cleveland, Ohio 44115*

both thermoplastic and thermosetting powder resins. Compositions containing as little as 4% to 7% by weight of Tullanox 500 in blends with epoxy, vinyl or polypropylene powders have rendered discontinuous coatings that display super-hydrophobic characteristics.

Earth Products — soils and sand[7]

Treatment of earth products such as soils and sand with Tullanox 500 yields hydrophobic products with a variety of uses. They can be made to remain completely dry when immersed in water and maintain a mass of associated air. They can be used as a waterproof fill for construction projects or to upgrade secondary roadways. Control of surface rain water run-off to minimize erosion or for water conservation are additional uses. When used as a fill for underground closures, they resist freezing, thus providing year-round access to underground facilities. As agricultural mulches, they tend to reduce weed growth and direct rain water run-off toward areas where it is desired. As an insulating fill around heated oil transmission pipe lines, they remain dry and act as an efficient heat insulator.

Super-hydrophobic sand can convey gases throughout its mass when it is submerged in water. It is being studied as a vehicle for introducing and maintaining an adequate air reservoir in activated sludge treatments of sewage. It also suggests application for use as an efficient means of introducing pure oxygen to the lower levels of polluted lakes and rivers.

Partial treatments of soils with Tullanox 500 render masses that are semi-hydrophobic. These can be used to regulate water uptake of golf green turfs, retard the surface water evaporation of soils for agriculture and prevent overwatering of potting soils.

Finely divided soils can be made super-hydrophobic by simply dry-blending 0.1% to 0.3% Tullanox 500 by weight with *dry* soil. If the soil is wet, the mass will not attain super-hydrophobicity until such time as it has reached a completely dry state. Thereafter it will resist water penetration. Soils can be made partially hydrophobic by incorporating Tullanox 500 at 0.07% to 0.09% by weight.

For larger aggregates such as sand, it has been found desirable to use polymeric binders for anchoring the Tullanox 500 particles to the substrates. Suitable binders include low viscosity (approximately 100 cps) liquid epoxy or polyester resins or curable silicone fluids.* Recommended concentrations are in the range of 0.1% to 0.3% by weight, both for binder solids and for Tullanox 500.

Dry sand is first tumbled with the catalyzed polymer in a rotating chamber — such as a cement mixer — to wet out the surfaces of the aggregates. While the polymer is curing and still in the tacky state, Tullanox 500 is introduced and becomes anchored to the surfaces. Heated aggregates can be used to effect a faster cure and shorter mixing cycles.

Seeds

Tullanox 500 powder can be used as a topcoat for pelleted seeds.[8] The hydrophobic nature of the coating allows for designing the pelleted seed to meet specific soil moisture conditions. For example, seeds can be produced that will germinate in adverse wet soil conditions. Dry-blending pelleted seeds with approximately 0.1% to 0.2% of Tullanox 500 has been found adequate for this application.

This rubber plant thrives on a mixed potting soil distributed by Dew Lane Associates, Canton, Mass. Containing Tullanox 500, the soil maintains optimum moisture conditions by absorbing water slowly at a uniform rate while the pot rests in a container of standing water. The plant has grown from the height indicated by the girl's hand since being potted in the soil mixture just two years ago.

** Silicone Fluid L-3, Union Carbide Chemicals and Plastics Division, 270 Park Ave., New York, N.Y. 10017*

Coatings — water resistance

The incorporation of Tullanox 500 at levels in the range of 1% to 3% by weight imparts a high degree of water resistance to coatings for many types of applications.

Clear acrylic coatings for masonry at 15% total solids provide water-shedding protection sufficient to prevent wetting of vertical surfaces in heavy rains or snowstorms. Protection is afforded against freeze-thaw cycles, leaching of soluble salts and attack by corrosive air pollutants. Yet the invisible coating leaves the surface looking completely untreated and allows the natural color, texture and beauty of the masonry to be seen. Other coating compositions[9] utilizing polysiloxanes, methacrylates and vinyl chloride copolymers as base polymers can be employed.

Similar coatings containing Tullanox 500 are used for wood primer finishes — to prevent swelling, warping and biological attack. Benefits provided in paints designed for marking uniform apparel are thickening and resistance to laundering.

In vinyl red lead shipboard primer formulated for Rule 66, Tullanox 500 has been found to give superior brushability, toughness and adhesion to steel. The incorporation of Tullanox 500 into zinc rich primers at levels of 0.3 to 1.0 parts per 187 parts of zinc reduces apparent settling, prevents hard settling and promotes ease of re-dispersion. It also improves the salt spray rating of top coats. In satin flatting varnishes, Tullanox 500 also acts as an anti-settling agent, improves flatting and improves viscosity control.

The performance of printed circuitry protected with conformal coatings containing Tullanox 500 displays little response to changes in atmospheric moisture.

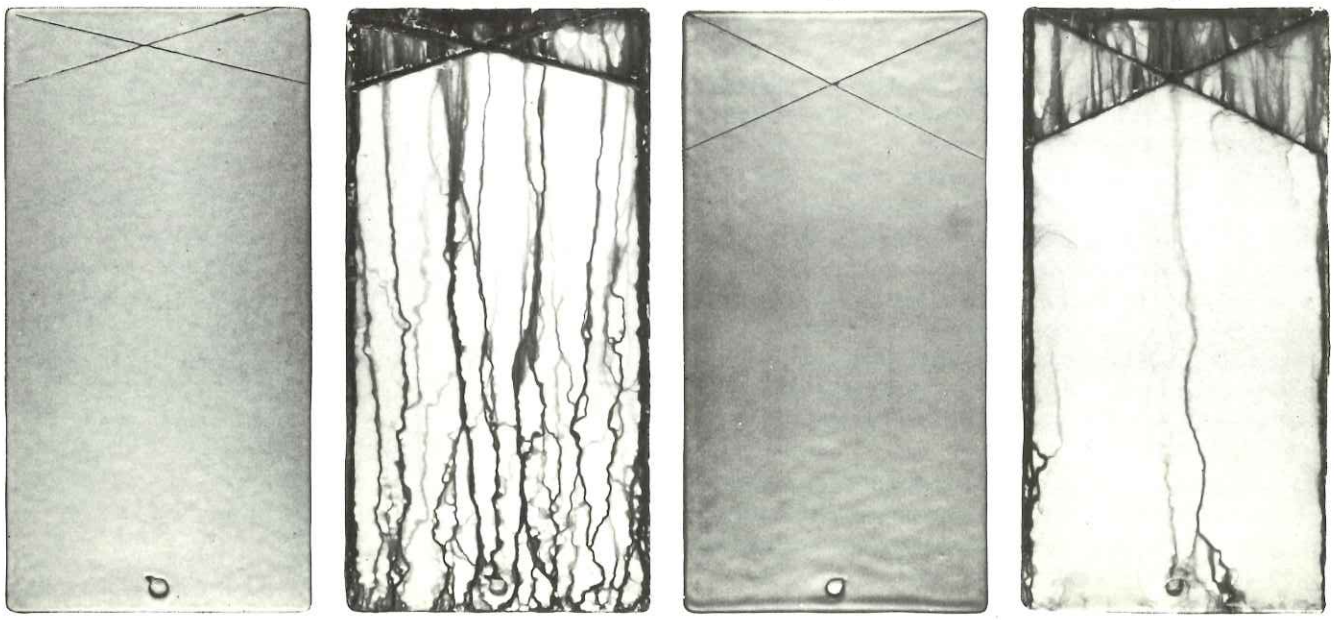
Suspended in suitable oils and emulsifiers, Tullanox 500 performs as the active ingredient in mold release coatings for the die casting of aluminum and other metals. Because of the high lubricity of Tullanox 500, these agents can be diluted 50 times or more with water before use. This makes them non-flammable, removing the fire hazard presented by older, organic formulations utilizing graphite as the active ingredient. The replacement of graphite and the dilution with water also eliminate the smoking — and the possible scorch marks on molded parts — common to older release agents.

Coating for chromatographic columns[10,11,12]

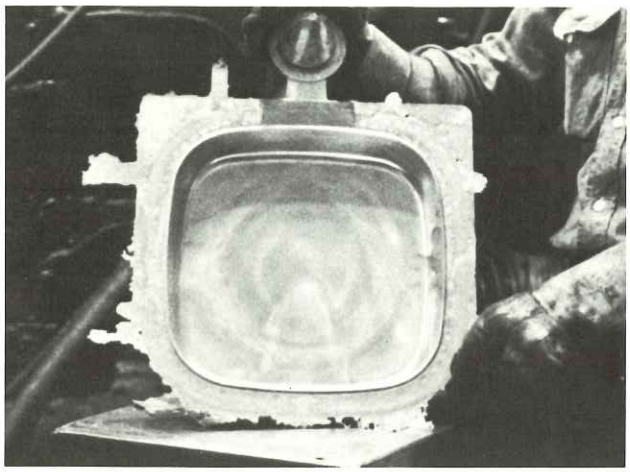
The fine particle size and lack of clumping make Tullanox 500 an ideal material for modifying the walls of capillary tubes for gas liquid chromatography (GLC). It can also be used as the support in the preparation of porous layer open tube (PLOT) columns. The Tullanox 500 is applied as a suspension in carbon tetrachloride, chloroform, or any other suitable liquid with a specific gravity high enough to enable dispersion stability. Silicones or other organic resins can be added as binders. Tubes thus coated before the addition of the stationary liquid phase can be used at temperatures up to 300°C. without beading of the liquid into microdroplets. Column preparation and conditioning are easy and fast, and performance is of a very high and stable quality.

Free flow and anti-caking

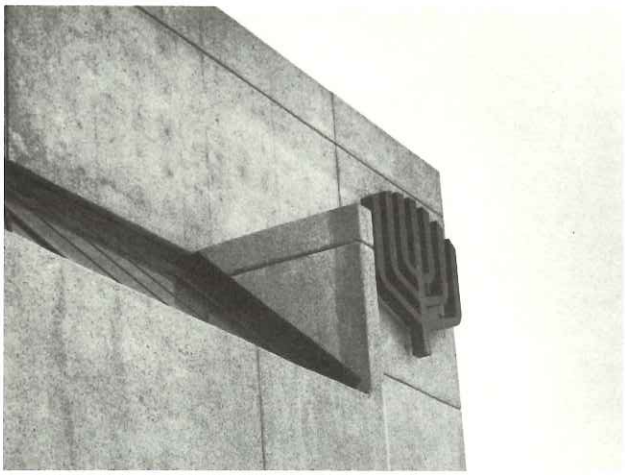
When mixed with other powders, the non-cohesive submicron particles of Tullanox 500 function as a vast number of spacers or "ball-bearings" between the larger particles of the other material.



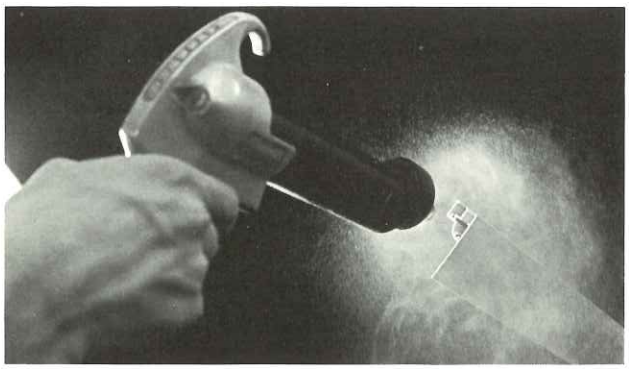
Salt spray tests on epoxy-based coatings over zinc rich primers. Photos A and B show a control panel before and after exposure of 1000 hours. The test panel in photos C and D is identical to the control in every way except that Tullanox 500 was incorporated into the top coat as a weathering aid.



Tullanox 500 is an active ingredient in non-flammable, highly efficient die release agents newly introduced to the aluminum casting industry. This electric skillet, fresh from the molds, exhibits no burn or scorch marks because of the non-flammable nature of the release coating.



Detail of Temple Beth Shalom in Spokane, Washington, coated with a water-repelling coating manufactured by United Paint Manufacturing, Inc., Spokane, incorporating Tullanox 500. On the abutment beside the symbolic Menorah (candlestick) a strip was left uncoated for comparison. After a rainy, snowy morning this area is wet and darkened, while the surrounding coated surfaces remain dry and unspotted.



In powdered polymers formulated for application by electrostatic spray gun techniques, Tullanox 500 improves free flow and electrical characteristics of the powder and uniformity of the coating.

This eliminates caking and promotes free flow of the powder. It also increases the bulk density, because the free flowing particles tend to settle more closely together, thus occupying the void spaces normally found in the untreated powder.

A particularly useful application of this function is made in the manufacture of powder fire extinguishers. The spray pattern is greatly improved by the free flowing character of the treated powder. And the weight of powder which can be packed into an extinguisher of given volume is sometimes increased as much as 12%. The concentration of Tullanox 500 required is in the range of 0.05% to 0.5% by weight. The absence of caking insures long shelf life and product dependability.

In powder coating fluidized bed and electrostatic gun deposition, Tullanox 500 enhances powder handling, conveying, deposition and fused polymeric film properties in these ways: enhanced free flow characteristics; greater and more uniform bed fluidization; increased apparent bulk density of the powder without caking; minimization of the problems associated with triboelectrification of powders, i.e., hang-up on container walls and clogging of transfer lines; increased attraction to the substrate of powders having intrinsically low resistivity; and minimized moisture absorption in the fused polymeric film.

In some instances, as little as 0.1% of Tullanox 500 by weight in dry powder polymers is enough to generate fluid-like free flow properties. When blended with expandable polystyrene particles[13] in concentrations of approximately 0.1%, it prevents clumping during both storage and pre-expansion operations. It insures ease of processing without impairing the fusion characteristics of the beads.

Oily powders — resorcinol[14] and encapsulated perfumes, for example — are especially benefited by blending with Tullanox 500. The non-polar surface of Tullanox 500 enables it to adsorb and "dry up" surface oiliness. After treatment with Tullanox 500, the water repellency imparted to the substrate makes it resistant to atmospheric moisture.

Powder diffraction samples of resorcinol and similar hygroscopic materials have been successfully pelleted by grinding with 5% Tullanox 500 by weight and compressing in a tablet mold at 10,000 psi. The pellet is relatively hydrophobic and has a high density of randomly oriented crystallites per unit area. Tullanox 500 does not interfere with the diffraction results.[15]

As little as 0.05%-0.1% hydrophobic silica added to fertilizers[16] greatly improves the anti-caking performance.

In powder aerosol products, the addition of Tullanox 500 at levels of 0.1% to 1.0% of the active ingredients eliminates hard settling in the can. This lack of settling and caking also prevents clogging of the aerosol nozzle.

Powders used for creating vapor trails from target aircraft[17] are found to have increased dispersibility — with

resulting increase in visibility — after the incorporation of Tullanox 500 to effect deagglomeration. The flow characteristics and dispersibility of inorganic fluorescent pigments used for atmospheric tracers[18] can be improved by the addition of hydrophobic silica. It also offers utility in insecticides, herbicides, fungicides, and other powder materials which depend on fine dispersion for optimum efficiency.

Hydrophobic silica is particularly beneficial in protecting finely divided powdered substances against agglomeration and reagglomeration during grinding processes.[19]

Thickening of liquids

Many liquids are thickened efficiently by Tullanox 500. For example, moderately polar lithographic inks thickened with Tullanox 500 at levels of 4% to 8% by weight have been found to have from 2 to 3 times the viscosity produced by the addition of the same concentration of hydrophilic colloidal silicas. Lithographic inks, lubricating greases and sealants can be thickened with accompanying high degrees of water repellency and relatively low levels of thixotropy.

In the case of highly polar ethylene glycol, the addition of 8% Tullanox 500 increases the viscosity from 18 cps to 27,000 cps and gives a Thixotropic Index of 5.87. The same amount of hydrophilic silica gives a final viscosity of only 100 cps and an Index of 1.39.

Functional additive for polymers

As an additive in epoxy solder systems[20], Tullanox 500 provides viscosity control with increases in strength and hardness. The water repellency of the cured compound is also improved. Tullanox 500 acts as a unique absorbent and can be used to dispense liquid anti-oxidants into specialty rubbers. Its resistance to moisture absorption makes it compatible with moisture-sensitive polyurethane systems, for use as a flatting agent.

In two-component RTV silicone rubber compositions, deammoniated Tullanox 500* offers low viscosity and high reinforcement capability. Additions as high as 10 phr in hydroxy-terminated polydimethylsiloxane (Brookfield viscosity — 1,000 cps) can produce a stable viscosity of only 16,000 cps and display a cured Shore A hardness value of 33 with a Die C tear value of 12 psi.

Tullanox 500 has also been found effective as a reinforcing agent for phosphonitrilic fluoroelastomers (PNF).[21] Incorporation of 10 to 40 phr in PNF stocks results in continuous increases in modulus, tensile strength and hardness, without affecting elongation. Tensile strength of 2380 psi can be achieved with 40 phr of Tullanox 500.

Colloidal surface active agent

Because Tullanox 500 surfaces contain both organic and inorganic groups, it behaves in a unique fashion to stabilize emulsions. When approximately 1% by weight is added to mixtures of oil and water with agitation, the particles orient themselves in the continuous oil phase and prevent coalescence of the water droplets. Unique water-in-oil emulsions having high viscosity and unusual stability can be created in this fashion.

If oil-in-water emulsions are desired, equal quantities of untreated hydrophilic fumed silica can be added to the formulations.

Liquid-in-air emulsions A unique property of hydrophobic silica is its ability to surround and encapsulate tiny droplets of water.[22] When small quantities are mixed with water under high shear conditions, the water is converted to a free flowing powder, and can be handled just like any other powder.

The end-result is the creation of a system which is literally "powdered water". A typical formulation for a powdered water mixture contains 61% air, 34% water, and 5% solids by volume — a true water-in-air emulsion. Emulsions of aqueous systems in air are prepared by combining in a high speed blender or Dispersator about 90% by weight of water with about 10% by weight of silica. Good emulsions are obtained at high speed settings, using a short mixing time — about 5 seconds.

These silica-water compositions are particularly beneficial in the germination of hard-to-grow seedlings.[23] Mixed with clays they allow seeds to germinate in a controlled environment. Seedlings can be removed from these fluffy beds for transplanting without damage to the sensitive root hair structures.

Oil slick burning agent[24]

Tullanox 500 can be applied in pure form onto an oil slick and the slick can then be ignited.[25] The wicking action of the Tullanox 500 allows the oil to rise above the water surface, where it becomes concentrated enough to burn. This wicking action also helps the oil to reach its ignition temperature more easily, since it is no longer cooled by the water. The hard crust left after burning can be easily scooped up from the surface of the water and disposed of.

* *See footnote page 2*

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Tullanox 500 is manufactured under licensing arrangements with Cabot Corporation, 125 High Street, Boston, Massachusetts 02110.

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